

# **Relocatable Models Development and Evaluation**

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## **LONG-TERM GOALS**

To develop, test, demonstrate and evaluate robust, user-friendly, relocatable ocean models for use in nowcast/forecast systems on tactical scales. Models developed and tested in this 6.2 program and transitioned into the 6.4 Small Scale Oceanography program for advanced development and testing and then for final evaluation under near real time operational conditions.

## **OBJECTIVES**

The objective of this project is to develop a robust globally relocatable ocean model and forecast system for U.S. Navy product enhancement. This will be done by determining the important issues that affect the relocatability of an ocean model, in both deep and shallow areas of the global ocean that are of Navy interest and addressing them individually. Although the issue of relocatability has been studied using simple barotropic ocean models (Preller et al., 2000 and Hubbert et al., 2000) for tide/surge prediction, the complexity of the problem increases dramatically when the ocean model is fully baroclinic. Problems such as model initialization, grid set up (both horizontal and vertical), adequate bathymetry and coastline data bases, boundary conditions, data assimilation, robustness of the model and user-friendliness are all key issues that will be addressed in this project. Once an appropriate model is developed and tested in regions of Navy interest, it is transitioned into the U.S. Navy's 6.4 programs for advanced developmental testing before transition into operations, the ultimate goal of the project.

## **APPROACH**

The approach used in this project is to address key issues for model relocatability individually and to build on existing work that has been done in the area of relocatable ocean models. Based on operational needs and lessons learned from a baseline capability using a relocatable Princeton Ocean Model, several key issues stand out as requiring further work in order to develop a truly robust, relocatable system. These issues are the setup of the model grid (both horizontal and vertical), model topography, open boundary conditions (including tides) and model coupling, model initialization, data

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assimilation and user-friendliness of the relocatability of the system. Several different oceanographic areas will be used to study these issues. Initial work will be done in both the eastern and western Pacific Ocean, representing areas of Navy interest and will progress to other locations representing varying dynamic and thermodynamic conditions. The project will build from the Princeton Ocean model codes to more flexible codes such as the NRL Coastal Ocean Model (NCOM) or other appropriate codes. The project will also build on simple data assimilation techniques such as nudging to other techniques that meet the operational needs of flexibility and computational limitation.

Key individuals working on this project are: Dr. Dong Shan Ko, code development, database upgrades, data assimilation, Paul Martin, providing improvements and expert guidance in the running of the NCOM model. Ms Shelley Riedlinger runs applications of these models, focusing on simulations associated with model coupling.

## **WORK COMPLETED**

The NAVO DBDB5 ocean topography has been used in the early version of the relocatable ocean model. It was reported that in many regions the model topography does not match well at the coastline. It has been determined that an uniform high resolution gridded global topography data set with matched coastline is needed for accurate and easy setup of the relocatable ocean model in any region of Navy interest. A 2-min global topography (DBDB2/NRL) has been developed based on the NAVO DBDBV, ETOPO5, the Smith and Sandwell data, the IBCAO Arctic data, the DAMEE north Atlantic data, and various data sets in the Gulf of Mexico and Yellow Sea. Each of the values chosen from these data sets was interpolated onto 2-min global grid. This 2-min topography was edited according to a high resolution coastline data from GMT. To accomplish the editing an interactive topography editor was developed. This editor has been provided to several other modeling projects for model topography editing. The DBDB2/NRL has been modified several times during the past year and given to NRL users to evaluate. Feedback from these evaluations has been used in the data base upgrade cycle. NRL DBDB2 as been applied to setup the model topography for the Northern South China Sea Nowcast/Forecast system (NSCSNFS).

The early version of the relocatable POM model applies MODAS fields for the open boundary conditions in a situation when no other boundary conditions are available. These fields include temperature, salinity, geostrophic current and dynamic height. In general these boundary conditions work well in the open ocean where geostrophy dominates. However, in many regions of ocean, particularly along the coast and in straits where barotropic forces are important, the model failed. It was determined that a large scale ocean model is needed to provide boundary conditions for a truly globally relocatable model. A one way coupling scheme has been developed to take advantage of the availability of fully 3-D large scale model fields for the open boundary conditions. The coupling scheme has been tested and some sensitivity study was done on the both the models run on the east and west (NSCSNFS) Pacific coast models.

The MODAS analysis which includes temperature, salinity, geostrophy current and dynamic height fields is used to initialize the relocatable model as a “cold start” when no other fields are available. If a large scale (global) model is available, those fields or those fields in conjunction with the MODAS data can be used. MODAS has also been applied to statistically infer surface observations to 3D temperature/salinity fields. A modified nudging technique was developed to assimilate these MODAS synthetics. A third way, and perhaps the best way, is to initialize the relocatable model with its own

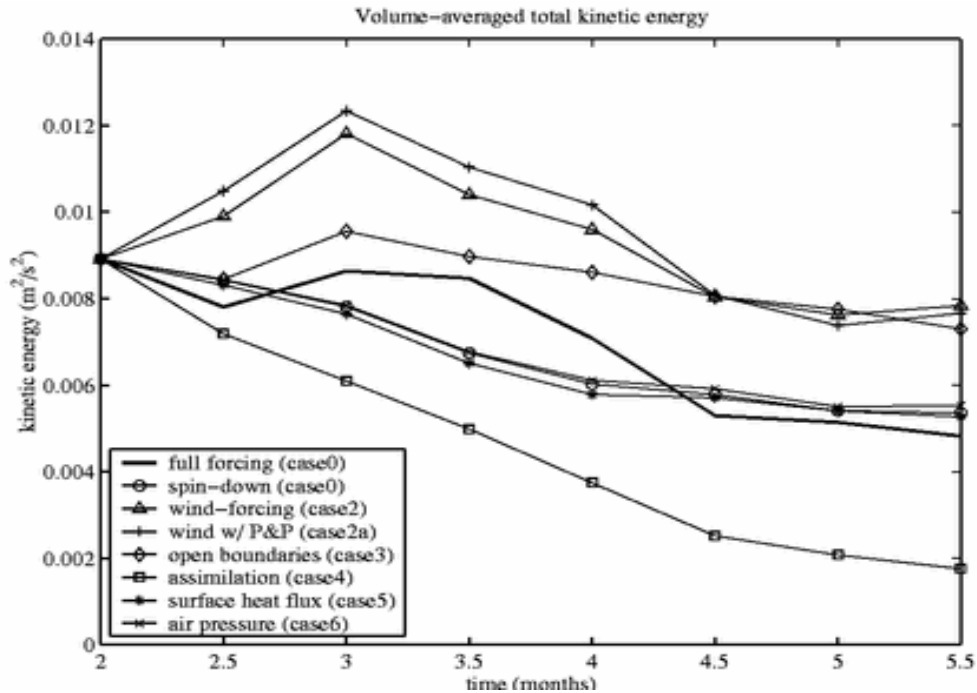
fields and continuously assimilate data to reach the nowcast state. As the Global NCOM model now exists, fields from this model have been used for both model initialization and boundary conditions.

During this year, the tasking under this project was redirected by the ONR Program Manager away from relocatability issues and focused on the use of our Northern South China Sea model to evaluate the ocean circulation in the northern South China Sea. In addition, we were directed to provide assistance upon request to colleagues in Singapore who are using the POM code to develop a model of the South China Sea.

## RESULTS

During this fiscal year, a series of experiments was run using our Northern South China Sea model to determine the dominant forcing driving the circulation in this region. This study used a  $1/24^{\text{th}}$  degree resolution POM model for the northern South China Sea. This model was provided boundary conditions from larger scale ( $1/4$  degree) north Pacific basin model. To evaluate the forcing effects, a diagnostic study was performed by repeatedly running the Northern South China Sea model, starting at the same forecast state, but applying the forcings individually. The results from test cases were then compared. We chose the time period for each run, February 1, 2001 to May 15, 2001 to encompass the second South China Sea field program associated with the ASIAEX project. Thirteen experiments were run and evaluated.

A preliminary examination of the volume-averaged kinetic energy for the model domain shows that the wind stress and the inflow through Luzon Strait provide most of the system kinetic energy (Figure 1).



**Figure 1. Volume averaged total Kinetic Energy from the northern South China Sea model for 8 case studies using different forcing.**

The lines drawn in Figure1 represent eight cases with full forcing (solid line), wind forcing only with the Pacanowski and Philander Richardson-number-dependent mixing (plus sign), wind forcing only with Mellor-Yamada level 2.5 mixing (triangle), open boundary forcing only (diamond), sea level pressure only (x), heat flux only (\*), data assimilation only (\*) and model run from initial state with no forcing (o).

These tests showed that for the part of the northern South China Sea that surface heat flux and atmospheric pressure make negligible contributions. Data assimilation has the dynamical effect of damping or relaxing the system to a much less energetic state. Without any forcing applied, the system produces large gyre-like circulations that form southwest of Taiwan and appear to propagate along the continental slope toward the southwest. These gyres can also be generated by the large wind-stress curl that occurs on the southwest side of Taiwan.

## **IMPACT/APPLICATIONS**

The impact of this project is to improve the Navy's baseline capability in relocatable global ocean forecasting. Output from this project will transition into operations through the SPAWARS 6.4 Small Scale Oceanography project and then will be used to upgrade the Navy's capability in global ocean prediction via the use of relocatable models.. The improvement of the bathymetry and coastline matching data bases this year can be used by other Navy modeling efforts. The model sensitivity studies (new direction for this year) will assist the ASIAEX PI's to understand the physical oceanography of this region.

## **TRANSITIONS**

None

## **RELATED PROJECTS**

NRL 6.1 LINKS project. Greg Jacob PI. Looks at the interaction of the three Western Pacific marginal seas

SPAWAR 6.4 Small Scale Oceanography project. Tests coastal ocean models in a real time forecasting scenario before they are delivered into operations.

ONR funded COAMPS project.

ONR funded ASIAEX project.

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## **PUBLICATIONS**

A paper on these sensitivity studies is being written by NRL and WHOI PI's as part of the ASIAEX special edition publication.